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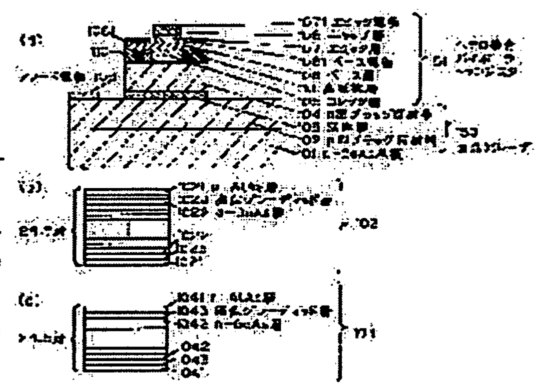
(54) OPTOELECTRONIC INTEGRATED CIRCUIT AND ITS MANUFACTURE

(57)Abstract:

PROBLEM TO BE SOLVED: To reduce a base-collector junction area and improve current cut-off frequency by increasing the resistance of the periphery of a collector layer, or a part of a base layer and the periphery of the collector layer by ion implantation or the like.

SOLUTION: For example, a p-type Bragg reflector 102 on an N-GaAs substrate 101, an active region 103 and an n-type Bragg reflector 104 construct a surface emission laser 150. Further, an n-GaAs collector layer 105 on the n-GaAs substrate 101, a p-GaAs base layer 106, an n-Al10.3Ga0.7As base electrode 1061, an emitter layer 107 and an emitter electrode 1071 construct a heterojunction bipolar transistor 151. A high resistance layer 110 is formed at the interface between the base layer 106 and the collector layer 105 and the periphery of the collector layer 105. This reduces a base-collector junction capacitance. The high resistance layer 110 is formed by, e.g. hydrogen ion implantation or oxygen ion implantation.



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CLAIMS

[Claim(s)]
[Claim 1] The optoelectronic integrated circuit with which the periphery section of the collector layer which is this a part of heterojunction bipolar transistor is formed into high resistance in the optoelectronic integrated circuit equipped with a semi-conductor substrate, the perpendicular resonator mold face luminescence laser which has the semi-conductor multilayers put on this semi-conductor substrate, and the heterojunction bipolar transistor which has the semi-conductor multilayers put on this semi-conductor substrate.
[Claim 2] The optoelectronic integrated circuit according to claim 1 said whose collector layer thickness is 500nm or more.
[Claim 3] The optoelectronic integrated circuit according to claim 1 or 2 in which said high resistive layer is formed by ion-implantation.
[Claim 4] An optoelectronic integrated circuit with an area of the collector layer which is this a part of heterojunction bipolar transistor in the optoelectronic integrated circuit equipped with a semi-conductor substrate, the perpendicular resonator mold face luminescence laser which has the semi-conductor multilayers put on this semi-conductor substrate, and the heterojunction bipolar transistor which has the semi-conductor multilayers put on this semi-conductor substrate smaller than the area of the base layer which is this a part of heterojunction bipolar transistor.
[Claim 5] In the optoelectronic integrated circuit equipped with a semi-conductor substrate, the perpendicular resonator mold face luminescence laser which has the semi-conductor multilayers put on this semi-conductor substrate, and the heterojunction bipolar transistor which has the semi-conductor multilayers put on this semi-conductor substrate The process which forms an emitter mesa by etching, and the process which forms in the bottom of this emitter mesa the base mesa which has a bigger area than the area of this emitter mesa by etching, The process which covers this emitter mesa and this base mesa with an insulator layer, and the process which forms this insulator layer in a bigger area than the area of this base mesa, The process which removes this a part of collector layer, or a part or all of a layer that is all under this collector layer and this collector layer by etching by using this insulator layer as a mask, The manufacture approach of the optoelectronic integrated circuit equipped with the process which removes the periphery section of this collector layer by etching, and the process which removes the up Bragg reflection machine of this perpendicular resonator mold face luminescence laser by etching by using this insulator layer as a mask from this exposed collector layer side face.
[Claim 6] A semi-conductor substrate and the perpendicular resonator mold face luminescence laser which has the semi-conductor multilayers put on this semi-conductor substrate, The emitter layer which consists of AlGaAs with n mold conductivity put on this semi-conductor substrate, It is AlAs in which the part joined to the base layer which consists of GaAs with p mold conductivity, and this base layer has n mold conductivity. The optoelectronic integrated circuit with which the periphery section of AlAs in this collector layer has oxidized in the optoelectronic integrated circuit equipped with the heterojunction bipolar transistor which has the collector layer which is GaAs in which the remaining layers have n mold conductivity.
[Claim 7] A semi-conductor substrate and the perpendicular resonator mold face luminescence laser which has the semi-conductor multilayers put on this semi-conductor substrate, The emitter layer which consists of AlGaAs with n mold conductivity put on this semi-conductor substrate, It is AlAs in which the part joined to the base layer which consists of GaAs with p mold conductivity, and this base layer has n mold conductivity. An optoelectronic integrated circuit with an area of AlAs smaller than the area of this base layer in which the remainder has n mold conductivity in this collector layer in the optoelectronic integrated circuit equipped with the heterojunction bipolar transistor which has the collector layer which is GaAs with n mold conductivity.
[Claim 8] The optoelectronic integrated circuit according to claim 6 or 7 change to AlAs in a collector layer and using AlGaAs.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the optoelectronic integrated circuit equipped with perpendicular resonator mold face luminescence laser and a heterojunction bipolar transistor, and its manufacture approach.
[0002]
[Description of the Prior Art] the optoelectronic integrated circuit which consists of conventional perpendicular resonator mold face luminescence laser and a conventional heterojunction bipolar transistor -- for example, photograph nick technology Letters -- there are the 5th volume, No. 9, and an example indicated by 1038 pages (1993) (Photon.Technol.Lett.Vol.5, No.9, and pp.1035-1038 (1993)) from 1035 pages.
[0003] This optoelectronic integrated circuit is explained. It is having layer structure which carried out crystal growth of perpendicular resonator mold face luminescence laser (following, VCSEL) and the GaAs/AlGaAs system heterojunction bipolar transistor (following, HBT) on the GaAs substrate at this order. VCSEL is removed by wet etching in the HBT layer on it, it is formed, and outgoing radiation of the laser beam is carried out from the field where opening of the HBT was removed and carried out. HBT is formed in the location which adjoined said VCSEL, and such VCSEL(s) and HBT are separated by the high resistive layer by the ion implantation. The anode of VCSEL and the emitter of HBT are tied with wiring, and these are electrically connected with the serial by things. The output light of VCSEL is modulated by HBT. Moreover, it is also possible to carry out laser oscillation by about about tenmicroampere base current according to the current amplification operation.
[0004] Moreover, there are JP,6-61580,A and USP No. 5283447 as an optoelectronic integrated circuit of the structure which carried out the laminating of VCSEL and the HBT to length.
[0005]
[Problem(s) to be Solved by the Invention] Although the device with which VCSEL and HBT which drives it were accumulated is proposed from the former, one to accumulate these on the same substrate is modulating the output light from VCSEL by HBT at high speed. Although the thing with the current cut-off frequency and maximum oscillation frequency of 100GHz or more is also reported by the HBT simple substance, when VCSEL is electrically connected to a serial at HBT, for resistance of a VCSEL part, the modulation rate of HBT is restricted and the current cut-off frequency and maximum oscillation frequency as an optoelectronic integrated circuit fall considerably.
[0006] In a Prior art, since VCSEL is connected to the emitter and the serial, if the resistance as an optoelectronic integrated circuit is considered from the size of those with 170ohms - 250ohm, an emitter, the base, and a collector, the high-speed modulation of GHz order is not expectable.
[0007] Then, by solving the above-mentioned conventional technical problem and reducing base collector junction capacity in the optoelectronic integrated circuit by which VCSEL is electrically connected to HBT at the serial, this invention prevents the fall of the current cut-off frequency by resistance of a VCSEL part, and offers the optoelectronic integrated circuit which can be modulated at high speed.
[0008]
[Means for Solving the Problem] In order to solve the above-mentioned technical problem, perpendicular resonator mold face luminescence laser and a heterojunction bipolar transistor solve a technical problem by four configurations described below in the optoelectronic integrated circuit accumulated on the same substrate.
[0009] As the 1st configuration, the periphery section of a collector layer, or a part of base layer and the periphery section of a collector layer are formed into high resistance with ion-implantation etc., and base collector junction area is reduced. Since current cut-off frequency fT can be enlarged by that cause, VCSEL can be driven at a high speed.
[0010] By setting collector layer thickness as 500nm or more as the 2nd configuration in addition to the 1st configuration, the capacity produced between a base electrode and the layer under a high resistive layer is reduced, and the base collector junction capacity as the whole is reduced.
[0011] As the 3rd configuration, base collector junction area is reduced by removing the periphery section of a collector layer, and the junction capacitance between these is reduced.
[0012] As the 4th configuration, an AlAs layer is put into an interface with a base layer in a collector layer, only this AlAs layer is formed into high resistance by oxidizing alternatively, and base collector junction capacity is reduced. Or base collector junction capacity is reduced by removing said AlAs layer alternatively with an acid or alkali.
[0013] With these means, each can realize the high-speed drive of an optoelectronic integrated circuit.
[0014]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained using drawing 8 from drawing 1 .
[0015] (Gestalt 1 of operation) The sectional view of the optoelectronic integrated circuit of the gestalt of the 1 operation in this invention is shown in drawing 1 .
[0016] After carrying out crystal growth of p mold Bragg reflection machine 102, a barrier layer 103, n mold Bragg reflection machine 104, the collector layer 105 that consists of n-GaAs, the base layer 106 which consists of p-GaAs, the emitter layer 107 which consists of n-AlGaAs, and the cap layer 108 which consists of a n-GaAs layer by the molecular beam epitaxy method on the n-GaAs substrate 101, the anode electrode 109, a base electrode 1061, and the emitter electrode 1071 are formed. p mold Bragg reflection machine 102, and an active region 103 and n mold Bragg reflection machine 104 constitute a surface emission-type laser 150, and luminescence from a barrier layer 103 is shut up and amplified by the resonator which consists of a p mold Bragg reflection machine 102 and an n mold Bragg reflection machine 104, and results in laser oscillation. Outgoing radiation of the laser beam from a surface emission-type

laser 150 is carried out from the rear face of the n-GaAs substrate 101 through the n-GaAs substrate 101.
[0017] In addition, said p mold Bragg reflection machine 102 consists of 24.5 pairs of things which made the pair the p-AlAs layer 1021 and the p-GaAs layer 1022 like drawing 1 (b). the false graded layer 1023 is between the p-AlAs layer 1021 and the p-GaAs layer 1022, and a presentation should pass p-AlxGa1-xAs (x goes to 0 from 1 by 0<=x<=1.) from p-AlAs -- aluminum concentration is changing to p-GaAs gradually.
[0018] Said n mold Bragg reflection machine 104 consists of 24.5 pairs of things which made the pair the n-AlAs layer 1041 and the n-GaAs layer 1042 like drawing 1 (c). there is a false graded layer 1043 in the n-AlAs layer 1041 and the n-GaAs layer 1042, and a presentation should pass n-AlGaAs (x goes to 0 from 1 by 0<=x<=1.) from n-AlAs -- aluminum concentration is changing to n-GaAs gradually.
[0019] moreover, the active region 103 -- a core [barrier layer / (8nm) / undoping In0.2Ga0.8As] -- carrying out -- the both sides -- Undoping GaAs (10nm) -- undoping aluminum0.5GaAs (50nm) is further formed in the both sides. 80nm of n-aluminum0.5GaAs(es) is formed in the both sides of Undoping AlGaAs at a time at p mold Bragg reflection machine side at p-aluminum0.5GaAs and n mold Bragg reflection machine side, respectively.
[0020] The n-GaAs collector layer 105, the p-GaAs base layer 106, the n-aluminum0.3Ga0.7As base electrode 1061, and the emitter layer 107 and the emitter electrode 1071 constitute the heterojunction bipolar transistor 151. The high resistive layer 110 is formed in the interface of the base layer 106 and a collector layer 105, and the periphery section of a collector layer 105, and is reducing base collector junction capacity. This high resistive layer 110 is formed of for example, hydrogen ion impregnation or an oxygen ion implantation.
[0021] The collector layer 105 and n mold Bragg reflection machine 104 have touched those interfaces, and the heterojunction bipolar transistor 151 and the surface emission-type laser 150 are electrically connected to the serial. For this reason, collector current turns into a current which drives a surface emission-type laser 150. Usually, since the threshold current of a surface emission-type laser 150 is 2-3mA, when a current amplification factor is 100, laser oscillation of the surface emission-type laser 150 will be carried out by the base current of 20-30microA according to a magnification operation of the heterojunction bipolar transistor 151. Thus, the laser beam as a signal light is obtained according to a current amplification operation by adding the very small signal current to the base layer 106.
[0022] Since according to our examination it turned out that it is important to reduce the junction capacitance of HBT in order to make a high speed drive VCSEL, this point is described. First, the current cut-off frequency fT of the heterojunction bipolar transistor 151 is explained.
[0023] It is more suitable for current gain to consider the current cut-off frequency used as 1 in the optoelectronic integrated circuit by which the surface emission-type laser 150 and the heterojunction bipolar transistor 151 are electrically connected to the serial, rather than it considers the maximum oscillation frequency from which power gain is set to 1, when considering a high-speed modulation, since the current drive of the surface emission-type laser 150 is carried out. The current cut-off frequency fT is expressed with (a formula 1), and is in inverse proportion to the emitter base junction capacitance Ceb and the base collector junction capacity Cbc.
[0024]
(Formula 1) fT=1/[2pi {re(Cbe+Cbc)+(Re+Rc)Cbc+taub+tauc}] The intrinsic emitter resistance of the part which, as for re, an emitter layer and a base layer touch in an interface, all the emitter resistance in which Re included contact resistance of an emitter electrode etc., and Rc are [the base transit time of a carrier and tauc of collector resistance and taub] the collector transit times of a carrier here, and re is [2ps(es) and tauc of 5ohms or less and taub] usually 1ps extent. Cbe and Cbc are expressed by (a formula 3), (a formula 4), and (a formula 5), respectively (formula 2).
[0025]
(Formula 2) Cbe=Ae {epsilonqNbe/2 (Vbi-V)} 1/2 (formula 3) Cbc=Ab {epsilonqNbc/2 (Vbi-V)} 1/2 (formula 4) Nbe=Nb-Ne/(Nb+Ne)
(Formula 5) Nbc=Nb-Nc/(Nb+Nc)
Here, for the carrier concentration of an emitter layer, and Nb, the carrier concentration of a base layer and Nc are [the electrical potential difference on which the amount of electronic charge and Vbi join built-in potential, and V joins / epsilon / a dielectric constant and q / a joint, and Ne / emitter area and Ab of the carrier concentration of a collector layer and Ae] base area. Since the carrier concentration of a base layer is larger than the carrier concentration of an emitter layer and a collector layer about single figure in the case of a heterojunction bipolar transistor, (a formula 4) and (a formula 5) are approximated like (a formula 7), respectively (formula 6).
[0026] (Formula 6) Nbe**Ne (formula 7) Nbe**Nc therefore (a formula 2), and (a formula 3) are approximated like (a formula 9), respectively (formula 8).
[0027] (Formula 8) Cbe=Ae {epsilonqNe/2 (Vbi-V)} 1/2 (formula 9) When emasculated by high resistance-ization or removing, capacity generates the lower part and lower collector layer of a base layer of Cbc=Ab {epsilonqNc/2 (Vbi-V)} 1 / 2 base electrodes between a base electrode and the part in which the collector layer remained. This capacity will be expressed with the same formula (formula 10) as the usual capacitor, and base collector junction capacity will be expressed with (a formula 11) using (a formula 9) and (a formula 10) after all.
[0028] (Formula 10) C=epsilonS/d -- here, S is the area of a base electrode and d is the thickness of a high resistive layer or a cavernous part.
[0029]

$$(式11)\quad Cbc \equiv Cint + Cext = Ab\{\varepsilon qNc/2\ (Vbi-V)\}1/2 + \varepsilon S/d$$

In (a formula 11), the 1st term of the right-hand side will be called Cint, and the 2nd term will be called Cext.
[0030] Cint is the capacity of the base section which operates as a transistor, and the collector section, and Cext is the capacity of a high resistive layer and the base section formed into high resistance.
[0031] In order to enlarge current cut-off frequency fT, Cbe+Cbc+(Re+Rc) Cbc must be made smaller than the above explanation. Among these, Re is decided with an emitter electrode surface product, an emitter electrode material, and a contact layer ingredient, and is several ohms to about tenohms. In the case of the optoelectronic integrated circuit with which the heterojunction bipolar transistor and the surface emission-type laser are connected with the serial, Rc is also mostly decided by the series resistance of a surface emission-type laser, and serves as magnitude of several 10 ohms from 10ohms. Therefore, it is necessary to reduce Cbe and Cbc for the improvement in fT. Cbc by which a multiplier (Re+Rc) is applied especially must be reduced.
[0032] Then, this invention is forming the high resistive layer 110 in the interface of the base layer 106 and a collector layer 105, and

the periphery section of a collector layer 105, makes base collector junction area small, and makes Cbc small. This means the reduction of Cbc by reduction of Ab in (a formula 11). This high resistive layer 110 forms a resist mask or Au mask after the emitter mesa formation which consists of an emitter layer 107, through the base layer 106, with ion-implantation, it pours a hydrogen ion or oxygen ion into a collector layer 105, quantity-izes [resistance-], and is formed. At this time, the base layer 106 of the part which touches a collector layer 105 in an interface is also formed into high resistance in part.

[0033] Thereby, since Cbc can be reduced, high-speed operation of the optoelectronic integrated circuit shown with the gestalt 1 of operation can be carried out.

[0034] (Gestalt 2 of operation) The sectional view of the optoelectronic integrated circuit of the gestalt of the 1 operation in this invention is shown in drawing 2 . Although the gestalt of this operation is the almost same configuration as the gestalt 1 of operation, the points which are setting thickness of a collector layer to 500nm differ.

[0035] After carrying out crystal growth of p mold Bragg reflection machine 202, a barrier layer 203, n mold Bragg reflection machine 204, the collector layer 205 that consists of n-GaAs, the base layer 206 which consists of p-GaAs, the emitter layer 207 which consists of n-AlGaAs, and the cap layer 208 which consists of a n-GaAs layer by the molecular beam epitaxy method on the n-GaAs substrate 201, the anode electrode 209, a base electrode 2061, and the emitter electrode 2071 are formed. p mold Bragg reflection machine 202, and a barrier layer 203 and n mold Bragg reflection machine 204 constitute a surface emission-type laser 250, and luminescence from a barrier layer 203 is shut up and amplified by the resonator which consists of a p mold Bragg reflection machine 202 and an n mold Bragg reflection machine 204, and results in laser oscillation. Outgoing radiation of the laser beam from a surface emission-type laser 250 is carried out from the rear face of the n-GaAs substrate 201 through the n-GaAs substrate 201.

[0036] In addition, said p mold Bragg reflection machine 202 consists of 24.5 pairs of things which made the pair the p-AlAs layer 2021 and the p-GaAs layer 2022. The false graded layer 2023 is between the p-AlAs layer 2021 and the p-GaAs layer 2022, and aluminum concentration is changing [the presentation] from p-AlAs to p-GaAs gradually through p-AlGaAs. Said n mold Bragg reflection machine 204 consists of 24.5 pairs of things which made the pair the n-AlAs layer 2041 and the n-GaAs layer 2042. There is a false graded layer 2043 in the n-AlAs layer 2041 and the n-GaAs layer 2042, and aluminum concentration is changing [the presentation] from n-AlAs to n-GaAs gradually through n-AlGaAs.

[0037] A collector layer 205, the base layer 206, a base electrode 2061, and the emitter layer 207 and the emitter electrode 2071 constitute the heterojunction bipolar transistor 251. The thickness of a collector layer 205 is 500nm in thickness. The high resistive layer 210 is formed in the interface of the base layer 206 and a collector layer 205, and the periphery section of a collector layer 205, and is reducing base collector junction capacity. This high resistive layer 210 is formed by approach which was described in the gestalt 1 of operation.

[0038] Usually, in the case of a heterojunction bipolar transistor simple substance, if a collector layer is thick, since it is disadvantageous for a raise in fT, a collector layer 205 will not be set to 500nm or more. It is because collector transit-time tauc becomes large. In (a formula 1), tauc is the magnitude of 2ps(es) at most, and does not become double 4ps(es) in the place which enlarged several 100nm of collector layers 205, either. However, it is more more effective to reduce Cbc which a multiplier (Re+Rc) is set to several 10 ohms, and requires this, since the surface emission-type laser 250 is connected to the heterojunction bipolar transistor 251 at the serial in the case of the gestalt of this operation.

[0039] In (a formula 11), it divides into Cint and Cext and thinks. What is necessary is just to reduce the base area Ab, in order to reduce Cint. This is realized by making base collector junction area small by the high resistive layer 210. On the other hand, (a formula 11) shows that Cext must enlarge thickness d of the high resistive layer 210. This means enlarging thickness of a collector layer 205.

[0040] In addition, in this example, although thickness of a collector layer 205 was set to 500nm, Cbc can be reduced that what is necessary is just 500nm or more.

[0041] (Gestalt 3 of operation) The sectional view of the optoelectronic integrated circuit of the gestalt of the 1 operation in this invention is shown in drawing 3 . The gestalt of this operation is considered as the configuration which removed the collector layer and reduced Cbc.

[0042] After carrying out crystal growth of p mold Bragg reflection machine 302, a barrier layer 233, n mold Bragg reflection machine 304, the collector layer 305 that consists of n-GaAs, the base layer 306 which consists of p-GaAs, the emitter layer 307 which consists of n-AlGaAs, and the cap layer 308 which consists of a n-GaAs layer by the molecular beam epitaxy method on the n-GaAs substrate 301, the anode electrode 309, a base electrode 3061, and the emitter electrode 3071 are formed. p mold Bragg reflection machine 302, and a barrier layer 303 and n mold Bragg reflection machine 304 constitute a surface emission-type laser 350, and luminescence from a barrier layer 303 is shut up and amplified by the resonator which consists of a p mold Bragg reflection machine 302 and an n mold Bragg reflection machine 304, and results in laser oscillation. Outgoing radiation of the laser beam from a surface emission-type laser 350 is carried out from the rear face of the n-GaAs substrate 301 through the n-GaAs substrate 301.

[0043] In addition, said p mold Bragg reflection machine 302 consists of 24.5 pairs of things which made the pair the p-AlAs layer 3021 and the p-GaAs layer 3022.

[0044] The false graded layer 3023 is between the p-AlAs layer 3021 and the p-GaAs layer 3022, and aluminum concentration is changing [the presentation] from p-AlAs to p-GaAs gradually through p-AlGaAs. Said n mold Bragg reflection machine 304 consists of 24.5 pairs of things which made the pair the n-AlAs layer 3041 and the n-GaAs layer 3042. There is a false graded layer 3043 in the n-AlAs layer 3041 and the n-GaAs layer 3042, and aluminum concentration is changing [the presentation] from n-AlAs to n-GaAs gradually through n-AlGaAs.

[0045] A collector layer 305, the base layer 306, a base electrode 3061, and the emitter layer 307 and the emitter electrode 3071 constitute the heterojunction bipolar transistor 351. The area of said collector layer 305 is smaller than the area of said base layer 306, and said n mold Bragg reflection machine 304. That is, it is a cavity directly under [periphery section] said base layer 306, and compared with the case where the area of a collector layer 305 and the area of the base layer 306 are equal, Ab in (a formula 11) becomes small and Cbc also becomes small. That is, increase of fT is expected from (a formula 1). Furthermore, if thickness of said collector layer 305 is set to 500nm or more, reduction of Cext of (a formula 11) is also realized and it is still more effective for reduction of Cbc.

[0046] In addition, in the gestalt of this operation, although [the area of said collector layer 305] it is smaller than the area of said n mold Bragg reflection machine 304, it may be the same area. Moreover, although the direction currently filled with air considers said cavernous part from a dielectric constant and is advantageous to reduction of Cext, it may fill with resin, SiO2, SiN, etc. Reduction of Cext is further expected rather than it considers as a high resistive layer like [these ingredients have a dielectric constant smaller than the semiconductor material which is an ingredient of a collector layer 305, and / when the gestalten 1 and 2 of operation describe].

[0047] The manufacture approach of the optoelectronic integrated circuit in this example is explained using drawing 4 . p mold Bragg reflection machine 402, a barrier layer 403, n mold Bragg reflection machine 404, a collector layer 405, the base layer 406, the emitter

layer 407, and the cap layer 408 are grown up to be this order on the n-GaAs substrate 401 by the molecular beam epitaxy method or metal-organic chemical vapor deposition (drawing 4 a). p mold Bragg reflection machine 402, and a barrier layer 403 and n mold Bragg reflection machine 404 constitute the perpendicular resonator mold face luminescence laser 450. A collector layer 405, the base layer 406, the emitter layer 407, and the cap layer 408 constitute the heterojunction bipolar transistor 451.

[0048] Next, 500nm or more of SiN film 409 is deposited, and it is processed into a predetermined configuration. Following formation of the emitter mesa 415 by the wet etching of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, and spreading on the whole substrate surface of a resist 400, oxygen plasma treatment is performed and etchback only of the resist on the SiN film 409 is carried out (drawing 4 b). The SiN film 409 is removed by the hydrofluoric acid, and lift off of the emitter electrode 410 is vapor-deposited and carried out (drawing 4 c).

[0049] After depositing SiO2 film 411 and processing a predetermined configuration, a collector layer 405 is exposed by wet etching (drawing 4 d). The base mesa 412 is formed at this process. SiO2 film 411 is removed, again, 500nm or more of SiO2 film 413 is deposited, and it is processed into a predetermined configuration. At this time, area of SiO2 film 413 is made larger than the area of the base mesa 412 (drawing 4 e).

[0050] It etches to the AlAs layer which is the n mold Bragg reflection machine 404 maximum upper layer by the wet etching by the mixed liquor which consists of a sulfuric acid, hydrogen peroxide solution, and water, and the collector mesa 414 is formed (drawing 4 f). Then, with the mixed liquor which consists of a citric acid, hydrogen peroxide solution, and water the collector layer 405 which the side face exposed, side etching is put in and made smaller than the area of the base mesa 412 (drawing 4 g). The heterojunction bipolar transistor 451 is formed at the process so far.

[0051] Reactive ion etching is again carried out by using SiO2 film 413 as a mask using chlorine gas, and n mold Bragg reflection machine 404 and a barrier layer 403 are removed. Said reactive ion etching stops directly under a barrier layer 403, and p mold Bragg reflection machine 402 is not etched. The perpendicular resonator mold face luminescence laser 450 is formed at this process. Finally, the anode electrode 416 is vapor-deposited after removing SiO2 film 413 (drawing 4 h).

[0052] In addition, although the wet etching by the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water was used for formation of the base mesa 414, and etching of a collector layer 405 by the manufacture approach in the gestalt of this operation, the reactive ion etching or reactive ion beam etching by chlorine gas may also be used.

[0053] (Gestalt 4 of operation) The sectional view of the optoelectronic integrated circuit of the gestalt of the 1 operation in this invention is shown in drawing 5 . With the gestalt of this operation, an AlAs layer is used for a part of collector layer, and Cbc is reduced by oxidizing this layer.

[0054] After carrying out crystal growth of p mold Bragg reflection machine 502, a barrier layer 503, n mold Bragg reflection machine 504, the 1st collector layer 505 that consists of n-GaAs, the 2nd collector layer 506 which consists of n-AlAs, the base layer 507 which consists of p-GaAs, the emitter layer 508 which consists of n-AlGaAs, and the cap layer 509 which consists of a n-GaAs layer by the molecular beam epitaxy method on the n-GaAs substrate 501, the anode electrode 510, a base electrode 5071, and the emitter electrode 5081 are formed. p mold Bragg reflection machine 502, and a barrier layer 503 and n mold Bragg reflection machine 504 constitute a surface emission-type laser 550, and luminescence from a barrier layer 503 is shut up and amplified by the resonator which consists of a p mold Bragg reflection machine 502 and an n mold Bragg reflection machine 504, and results in laser oscillation. Outgoing radiation of the laser beam from a surface emission-type laser 550 is carried out from the rear face of the n-GaAs substrate 501 through the n-GaAs substrate 601.

[0055] In addition, said p mold Bragg reflection machine 602 consists of 24.5 pairs of things which made the pair the p-AlAs layer 5021 and the p-GaAs layer 5022. The false graded layer 5023 is between the p-AlAs layer 5021 and the p-GaAs layer 5022, and aluminum concentration is changing [the presentation] from p-AlAs to p-GaAs gradually through p-AlGaAs. Said n mold Bragg reflection machine 504 consists of 24.5 pairs of things which made the pair the n-AlAs layer 5041 and the n-GaAs layer 5042. There is a false graded layer 5043 in the n-AlAs layer 5041 and the n-GaAs layer 5042, and aluminum concentration is changing [the presentation] from n-AlAs to n-GaAs gradually through n-AlGaAs.

[0056] Collector layers 505 and 506, the base layer 507, a base electrode 5061, and the emitter layer 508 and the emitter electrode 5081 constitute the heterojunction bipolar transistor 551. The periphery section of the 2nd collector layer 506 oxidizes, and serves as the AlAsOx layer 511. By formation of the AlAsOx layer 511, the collector base plane-of-composition product Cbc becomes small, and fT increases from (a formula 1).

[0057] Although the about several ohms increment in the collector resistance by the hetero interface of GaAs/AlAs is considered in a collector layer, since the surface emission-type laser 550 is connected with the serial at the collector layer 605 and there are several 10ohms of resistance of this part with the gestalt of this operation, the increment in fT by Cbc reduction is more effective than the reduction of fT by the increment in collector resistance.

[0058] Here, drawing 6 is used and explained to the optoelectronic integrated circuit in the gestalt of this operation about the manufacture approach.

[0059] p mold Bragg reflection machine 602, a barrier layer 603, n mold Bragg reflection machine 604, the collector layer 605 that consists of n-GaAs, the collector layer 606 which consists of n-AlAs, the base layer 607, the emitter layer 608, and the cap layer 609 are grown up to be this order on the n-GaAs substrate 601 by the molecular beam epitaxy method or metal-organic chemical vapor deposition (drawing 6 a). p mold Bragg reflection 602, a barrier layer 603, and n mold Bragg reflection machine 604 constitute the perpendicular resonator mold face luminescence laser 650. Collector layers 605 and 606, the base layer 607, the emitter layer 608, and the cap layer 609 constitute the heterojunction bipolar transistor 651.

[0060] The base mesa 653 is formed for the emitter mesa 652 from ******** of a citric acid, hydrogen peroxide solution, and water by the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, respectively. The emitter electrode 6521 is formed on the emitter mesa 652, and the base electrode 6531 is formed on the base mesa 653, respectively (drawing 6 b).

[0061] 500nm or more of SiO2 film 610 is deposited, and it is processed into a predetermined configuration. At this time, area of SiO2 film 610 is carried out more than the area of the base mesa 653. Collector layers 605 and 606 are etched by the mixed liquor which consists of a sulfuric acid, hydrogen peroxide solution, and water (drawing 6 c). In this condition, the n-GaAs substrate 701 in the gestalt of this operation is put into a 400-degree C furnace, and the nitrogen gas which carried out bubbling in the pure water kept at 85 degrees C is introduced into the aforementioned furnace. At this time, the nitrogen gas introduced into the furnace contains a lot of steams, oxidizes alternatively only the collector layer 606 which consists of n-AlAs, and forms the AlAsOx layer 612 in the periphery section (drawing 6 d).

[0062] Reactive ion etching is again carried out by using SiO2 film 610 as a mask using chlorine gas, and n mold Bragg reflection machine 604 and a barrier layer 603 are removed. Said reactive ion etching stops directly under a barrier layer 703, and p mold Bragg reflection machine 602 is not etched (drawing 6 e). The perpendicular resonator mold face luminescence laser 650 is formed at this process. Finally, the anode electrode 611 is vapor-deposited.

[0063] In addition, although the wet etching by the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water or a citric acid, hydrogen peroxide solution, and water was used for formation of the emitter mesa 652 and the base mesa 653, and etching of collector layers 605 and 06 by the manufacture approach in the gestalt of this operation, the reactive ion etching or reactive ion beam etching by chlorine gas may also be used. Moreover, if there is 10nm or more of thickness of a collector layer 606, selective oxidation will advance to the interior. Furthermore, the presentation of a collector layer 606 is changed to n-AlAs, and it does not matter as n-AlGaAs.

[0064] (Gestalt 5 of operation) The sectional view of the optoelectronic integrated circuit of the gestalt of the 1 operation in this invention is shown in drawing 7 .

[0065] After carrying out crystal growth of p mold Bragg reflection machine 702, a barrier layer 703, n mold Bragg reflection machine 704, the 1st collector layer 705 that consists of n-GaAs, the 2nd collector layer 706 which consists of n-AlAs, the base 707 which consists of p-GaAs, the emitter layer 708 which consists of n-AlGaAs, and the cap layer 709 which consists of a n-GaAs layer by the molecular beam epitaxy method on the n-GaAs substrate 701, the anode electrode 710, a base electrode 7071, and the emitter electrode 7081 are formed. p mold Bragg reflection machine 702, and a barrier layer 703 and n mold Bragg reflection machine 704 constitute a surface emission-type laser 750, and luminescence from a barrier layer 703 is shut up and amplified by the resonator which consists of a p mold Bragg reflection machine 702 and an n mold Bragg reflection machine 704, and results in laser oscillation. Outgoing radiation of the laser beam from a surface emission-type laser 750 is carried out from the rear face of the n-GaAs substrate 701 through the n-GaAs substrate 701.

[0066] In addition, said p mold Bragg reflection machine 702 consists of 24.5 pairs of things which made the pair the p-AlAs layer 7021 and the p-GaAs layer 7022. The false graded layer 7023 is between p-AlAs7021 and the p-GaAs layer 7022, and aluminum concentration is changing [the presentation] from p-AlAs to p-GaAs gradually through p-AlGaAs. Said n mold Bragg reflection machine 604 consists of 24.5 pairs of things which made the pair the n-AlAs layer 7041 and the n-GaAs layer 7042. There is a false graded layer 7043 in the n-AlAs layer 7041 and the n-GaAs layer 7042, and aluminum concentration is changing [the presentation] from n-AlAs to n-GaAs gradually through n-AlGaAs.

[0067] Collector layers 705 and 706, the base layer 707, a base electrode 7061, and the emitter layer 708 and the emitter electrode 7081 constitute the heterojunction bipolar transistor 751. The periphery section of the 2nd collector layer 706 is removed, and is smaller than the area of the base layer 707. Thereby, the collector base plane-of-composition product Cbc becomes small, and fT increases from (a formula 1).

[0068] Although the about several ohms increment in the collector resistance by the hetero interface of GaAs/AlAs is considered in the 1st and 2nd collector layer, since the surface emission-type laser 750 is connected with the serial at the collector layer 705 and there are several 10ohms of resistance of this part with the gestalt of this operation, the increment in fT by Cbc reduction is more effective than the reduction of fT by the increment in collector resistance.

[0069] Here, drawing 8 is used and explained to the optoelectronic integrated circuit in the gestalt of this operation about the manufacture approach.

[0070] p mold Bragg reflection machine 802, a barrier layer 803, n mold Bragg reflection machine 804, the collector layer 805 that consists of n-GaAs, the collector layer 806 which consists of n-AlAs, the base layer 807, the emitter layer 808, and the cap layer 809 are grown up to be this order on the n-GaAs substrate 801 by the molecular beam epitaxy method or metal-organic chemical vapor deposition (drawing 8 a). p mold Bragg reflection 802, a barrier layer 803, and n mold Bragg reflection machine 804 constitute the perpendicular resonator mold face luminescence laser 850. Collector layers 805 and 806, the base layer 807, the emitter layer 808, and the cap layer 809 constitute the heterojunction bipolar transistor 851.

[0071] The emitter mesa 852 is formed by the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water, and the base mesa 853 is formed by the mixed liquor of a citric acid, hydrogen peroxide solution, and water. The emitter electrode 8521 is formed on the emitter mesa 852, and the base electrode 8531 is formed on the base mesa 853, respectively (drawing 8 b).

[0072] 500nm or more of SiO2 film 810 is deposited, and it is processed into a predetermined configuration. At this time, area of SiO2 film 810 is carried out more than the area of the base mesa 853. Collector layers 805 and 806 are etched by the mixed liquor which consists of a sulfuric acid, hydrogen peroxide solution, and water (drawing 8 c). It is immersed in a hydrofluoric acid in this condition, the periphery section of the collector layer 806 which consists of n-AlAs is removed, and it is made smaller than the area of the base layer 807 (drawing 8 d).

[0073] Reactive ion beam etching is again carried out by using SiO2 film 810 as a mask using chlorine gas, and n mold Bragg reflection machine 804 and a barrier layer 803 are removed. Said reactive ion beam etching stops directly under a barrier layer 803, and p mold Bragg reflection machine 802 is not etched (drawing 8 e). The perpendicular resonator mold face luminescence laser 850 is formed at this process. Finally, the anode electrode 811 is vapor-deposited.

[0074] In addition, although the wet etching by the mixed liquor of the mixed liquor of a sulfuric acid, hydrogen peroxide solution, and water or a citric acid, hydrogen peroxide solution, and water was used for formation of the emitter mesa 852 and the base mesa 853, and etching of collector layers 805 and 806 by the manufacture approach in the gestalt of this operation, the reactive ion etching or reactive ion beam etching by chlorine gas may also be used. Moreover, the presentation of a collector layer 806 is changed to n-AlAs, and it does not matter as n-AlGaAs.

[0075]

[Effect of the Invention] As mentioned above, according to this invention, by forming a part of collector layer into high resistance, or making area of a collector layer smaller than the area of a base layer, base collector junction area can be reduced, consequently the current cut-off frequency fT can be increased. Thereby, the high-speed drive of the optoelectronic integrated circuit with which the surface emission-type laser and the heterojunction bipolar transistor were accumulated on the same substrate is realized.

[Translation done.]

* NOTICES *

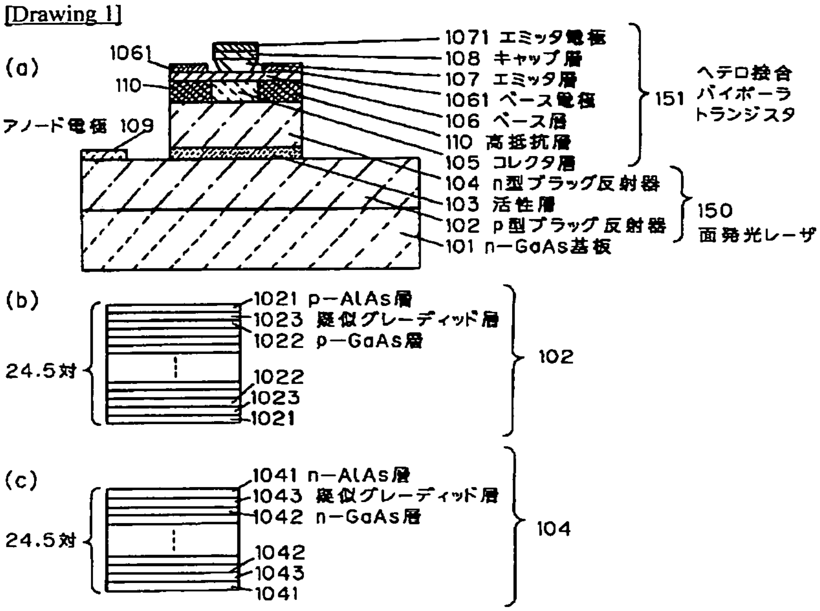
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 2] The sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 3] The sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 4] The process sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 5] The sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 6] The process sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 7] The sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Drawing 8] The process sectional view of the optoelectronic integrated circuit in the gestalt of 1 operation of this invention
[Description of Notations]
101 N-GaAs Substrate
102 P Mold Bragg Reflection Machine
103 Barrier Layer
104 N Mold Bragg Reflection Machine
105 Collector Layer
106 Base Layer
107 Emitter Layer
108 Cap Layer
110 High Resistive Layer
506 N-AlAs Collector Layer
511 AlAsOx Layer
706 N-AlAs Collector Layer
806 N-AlAs Collector Layer

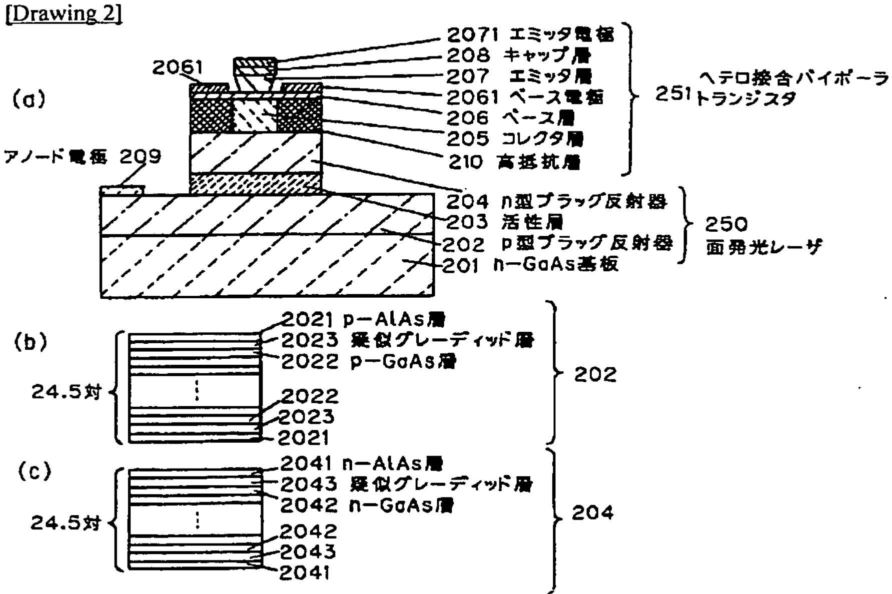
[Translation done.]

DRAWINGS

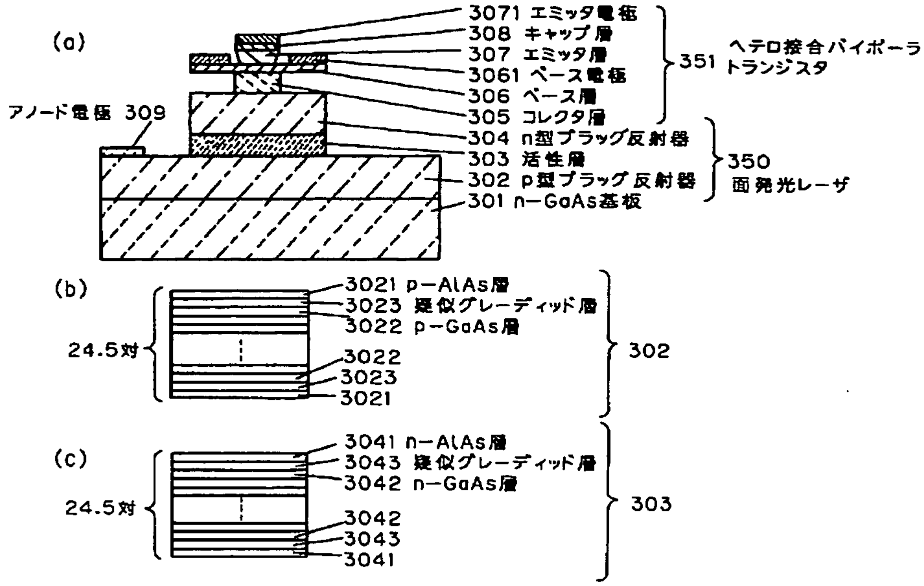
[Drawing 1]



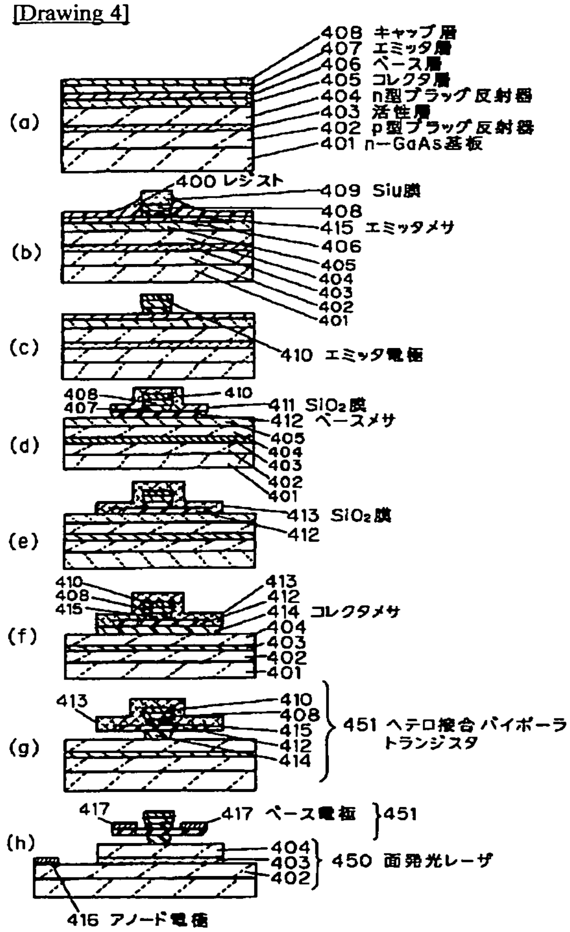
[Drawing 2]



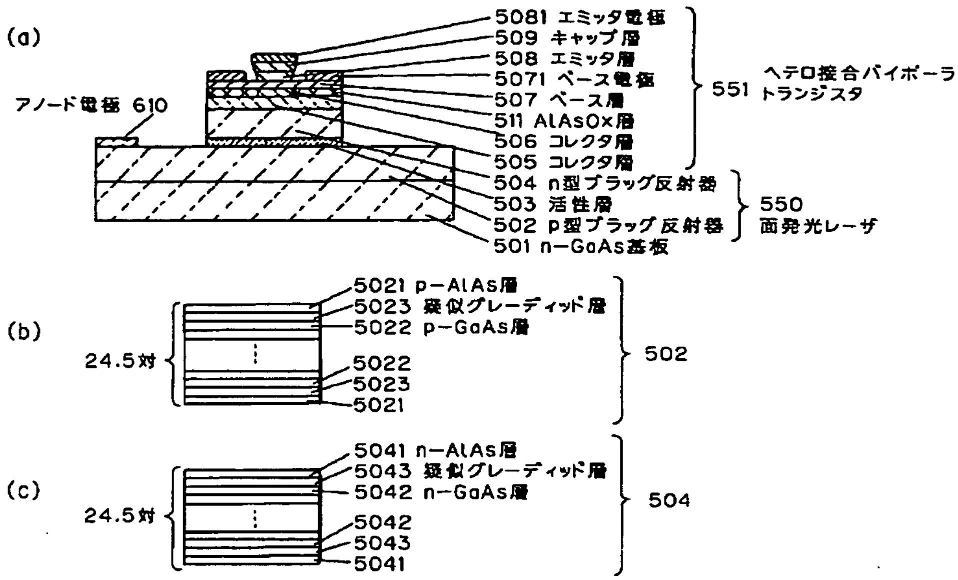
[Drawing 3]



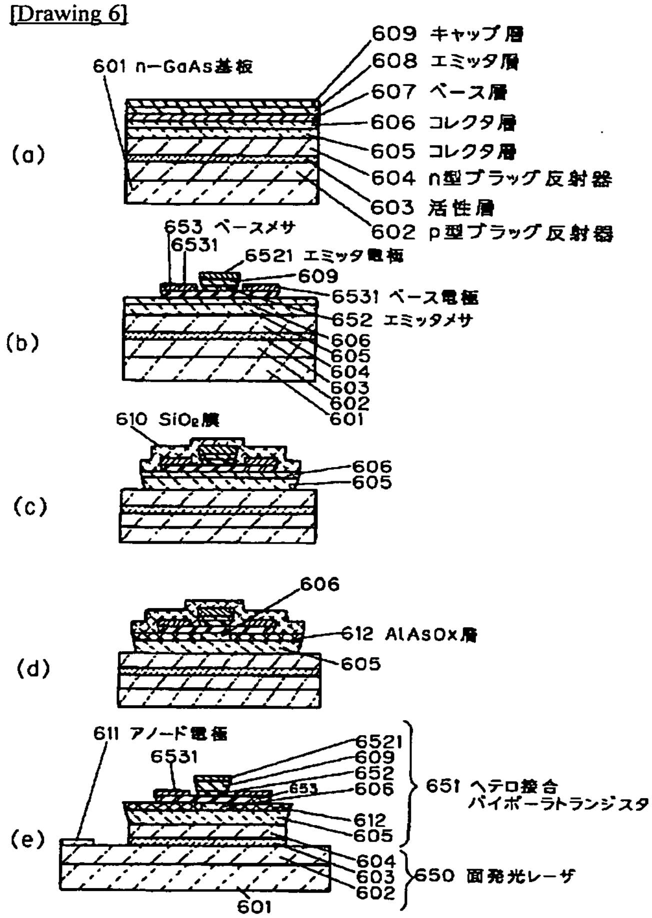
[Drawing 4]



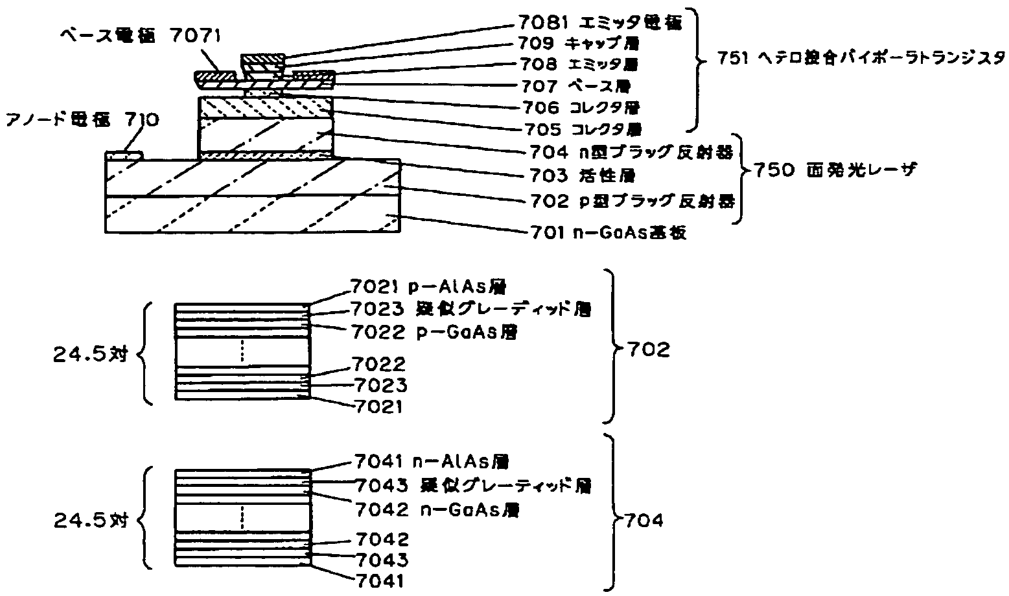
[Drawing 5]



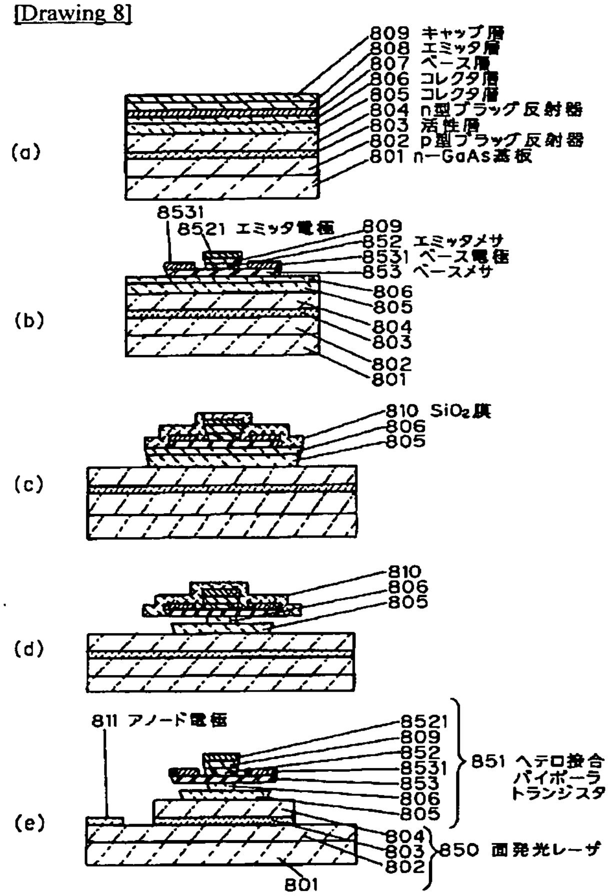
[Drawing 6]



[Drawing 7]



[Drawing 8]



[Translation done.]